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Cover illustration
The dots on the map represent
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INTRODUCTION

La région agricole des Prairies canadiennes se caractérise par un climat continental au régime hydrique semi-aride à subhumide. Le gros de la production agricole de cette région se fait en culture sèche. La production dépend de la fiabilité des précipitations et de la capacité du sol d'emmagasiner de l'eau. Les pluies en saison de croissance sont souvent très variables et il arrive souvent que cette variabilité augmente avec la diminution des précipitations totales. La capacité du sol d'emmagasiner les précipitations qui surviennent en dehors de la saison de croissance (hivernage) et la possibilité pour les cultures de disposer de cette eau sera de nature à réduire le risque que la production peut courir. Il est prouvé (Staple et Lehane, 1954; Lehane et Staple, 1965; Robertson, 1974; Bole et Pitman, 1980) que l'eau du sol emmagasinée au printemps et que les pluies tombées en saison de croissance sont pour la production céréalière l'équivalent de «précipitations efficaces» ou de source d'eau disponible. Les données sur l'apport, la distribution et la fiabilité de l'eau disponible pendant la saison de croissance et certains stades phénologiques clés du développement des cultures sont donc déterminantes pour assurer une agriculture viable et durable. Ces données sont essentielles aux agriculteurs pour les aider à planifier leurs techniques de gestion de l'eau du sol et aux décideurs pour leur permettre d'élaborer des programmes de sécurité du revenu et différents autres programmes.

Les principaux sols agricoles de la région des Prairies sont les sols chernozémiques bruns, brun foncé, noirs et gris foncé et, dans une moindre mesure, quelques Luvisols gris (voir fig. 1). Ces sols sont répartis de façon un peu concentrique autour de la zone la plus sèche de la région, soit le sud-ouest de la Saskatchewan et le sud-est de l'Alberta. Cette répartition témoigne d'une succession climatique liée à l'augmentation de la disponibilité de l'eau qui rayonne vers l'extérieur de cette zone (Acton et al., 1980). Mais les sols de chacune de ces principales zones de sols peuvent être de texture variable et donc posséder des capacités de rétention d'eau différentes. La quantité d'eau emmagasinée au printemps dépend de la capacité de rétention d'eau communément appelée capacité de rétention d'eau disponible (CRED), des conditions météorologiques au cours de la saison de croissance précédente, de l'hiver et des premiers mois du printemps, ainsi que de la pratique de la jachère l'année précédente.

La culture du blé de printemps, de l'orge, des oléagineux, des fourrages et la jachère sont les principales utilisations de sol de la région, mais leur répartition proportionnelle varie considérablement entre les diverses zones de sols. Le blé et la jachère (de même que les parcours sur les sols marginaux) constituent les utilisations les plus fréquentes dans les zones les plus sèches et les plus chaudes, mais diminuent progressivement en allant vers le nord. L'orge, les fourrages et l'avoine montrent une répartition inverse caractérisée par une faible proportion dans le sud et des superficies généralement plus grandes en allant vers le nord. Les oléagineux montrent une répartition égale, mais moins régulière. Les pâturages améliorés sont généralement comparables dans toutes les régions, sauf dans le «grand» nord sur Luvisols gris où ils occupent une superficie beaucoup plus grande de terres agricoles.

Le rendement économique de l'agriculture s'écarte de ce modèle et a tendance à témoigner plus fidèlement des débouchés et des possibilités du marché. Le capital investi et les ventes totales par hectare cultivé sont plus élevés dans les zones de sols chernozémiques noirs et plus faibles vers le sud et le nord. Mais les dépenses d'exploitation à l'hectare sont beaucoup moindres dans le sud de sorte que les marges bénéficiaires brutes sont relativement comparables dans toutes les régions (sauf dans les zones de Luvisols gris foncé et gris où elles sont plus faibles) (Huffman, 1988). Ces résultats témoignent de la tendance des agriculteurs de la zone des sols chernozémiques bruns qui est plus sèche à utiliser de plus faibles niveaux d'intrants parce que l'apport et la répartition des précipitations au cours de la saison de croissance sont aléatoires, tout comme la réaction des cultures à l'apport d'intrants.

Des études (Campbell et al., 1987, 1988; De Jong et Halstead, 1986 et Henry et al., 1986) ont révélé que grâce aux techniques actuelles de gestion, l'efficacité de l'eau conservée est beaucoup plus élevée que par le passé même si la quantité est la même. C'est à cause de la disponibilité de nouvelles variétés de culture et de la grande amélioration de la conduite des cultures. Il est prouvé (J. L. Henry, communication personnelle) qu'il faut environ 65 mm d'eau disponible dans la zone des sols bruns avant de pouvoir espérer obtenir un quelconque rendement du blé. Mais cette quantité diminue progressivement à 48, 41 et 38 mm dans les zones de sols brun foncé, noirs et gris foncé respectivement. Au-delà de ces seuils, on peut s'attendre à des augmentations de rendement, allant d'environ 9,2 kg/ha dans la zone des sols bruns à 12,5 kg/ha dans celle des sols gris, pour chaque millimètre supplémentaire d'eau dont la plante en croissance peut disposer. Par conséquent, les données sur les réserves d'eau du sol au printemps et sur la quantité de pluie prévue dans une région donnée sont très importantes pour évaluer le rendement, et les données sur la quantité probable d'eau disponible dans le sol au printemps et de pluie en saison de croissance est essentielle à l'évaluation du risque que court la production.

Habituellement, on exprime l'apport d'eau par précipitation sous forme de moyennes arithmétiques à long terme même si la pluie est un phénomène aléatoire ou stochastique. Cette étude s'écarte d'une telle démarche en présentant l'information en termes de niveaux variables de probabilité plutôt que de moyennes (le seuil de probabilité de 50 % équivaut à la moyenne arithmétique). Elle compile également l'information au moyen d'un modèle d'eau du sol qui intègre la précipitation quotidienne pendant 30 ans à la capacité de rétention d'eau du sol pour évaluer la quantité d'eau dont dispose chaque jour le blé de printemps à chaque période de croissance. En outre, elle fournit des évaluations pour les divers stades phénologiques de croissance et diverses rotations de cultures. Ces évaluations portent sur différentes capacités de rétention d'eau du sol dans chacune des zones de sols (zones de ressources agro-écologiques). Les résultats figurent sous forme de cartes montrant la répartition de l'eau du sol disponible à divers seuils de probabilité, et ce, pour les CRED les plus courantes de chaque région. Cette information permet de mieux comprendre la variabilité de l'eau disponible dans le sol dans les diverses régions des Prairies canadiennes et la probabilité d'un niveau donné de précipitation en saison de croissance. Elle témoigne de divers niveaux de risque que court la production et peut servir d'auxiliaire à la prise de décisions sur les pratiques culturales comme le semis, la jachère ou la rotation prolongée. Elle peut également servir à la prise de décisions en matière de politiques et de programmes.

INTRODUCTION

The agricultural region of the Canadian prairies has a continental climate, with semi-arid to subhumid moisture regimes. Most of the agricultural production in this region is based on dry-land farming. The risk of crop production depends on the reliability of precipitation and the ability of the soil to store water. Growing season rainfall is often highly variable and it is not unusual that rainfall variability increases as total precipitation decreases. The ability of the soil to store non-growing season (overwinter) precipitation and make it available to the growing crop will buffer the risk. It has been shown (Staple and Lehane, 1954; Lehane and Staple, 1965; Robertson, 1974; Bole and Pitman, 1980) that spring stored soil water and growing season rainfall can be considered together as available water or "effective precipitation" with regard to grain production. Therefore, information on the supply, distribution and reliability of available water during the growing season and during certain critical phenological stages in the development of the crop is critical for a viable and sustainable agriculture. The information is very important to farmers for planning soil water storage management techniques, and for policy makers for developing safety nets and other programs.

The major agricultural soils in the prairie region are the Brown, Dark Brown, Black and Dark Gray Chernozemic soils, and to a lesser extent some of the Gray Luvisol soils (see Fig. 1). These soils are distributed in a somewhat concentric manner around the driest area of the region, which is southwestern Saskatchewan and southeastern Alberta. This reflects a climate sequence related to increasing available water, which radiates outward from this area (Acton et al., 1980). Individual soils within each of these major soil zones however, can be of varying textures, and consequently varying soil water holding capacities. The amount of water stored in the spring depends upon the water holding capacity, commonly called Available Water-holding Capacity (AWC), the weather conditions during the previous growing season, winter and early spring months and whether or not the land was fallowed the previous year.

Spring wheat, barley, oilseeds, forages and summerfallow are the dominant land uses in the region, but the proportional distribution of these varies considerably among the soil zones. Wheat and summerfallow (as well as rangelands on the marginal soils) are most common land uses in the driest and warmest areas, but decrease gradually to the north. Barley, forages and oats show a converse distribution, with low proportions in the south and generally increasing areas towards the north. Oilseeds are similarly distributed, but in a less regular pattern. Improved pasture is generally similar in all areas, except in the 'far' north on Gray Luvisol soils, where it occupies a much higher proportion of agricultural land.

Economic performance of agriculture deviates from this

pattern, tending to reflect market potentials and opportunities more closely. Capital investment and total sales per cultivated hectare are highest in the Black Chernozemic areas, and lower to the south and north. Operating expenses per hectare, however, are considerably lower in the south, with the result that gross margins are relatively similar in all regions (except for the Dark Gray and Gray Luvisol areas, where they are lower) (Huffman, 1988). This reflects the tendency of farmers in the drier, Brown Chernozemic soils to use lower levels of inputs because the supply and distribution of precipitation during the growing season is unreliable, as is crop response to inputs.

Studies (Campbell et al., 1987; 1988, De Jong and Halstead, 1986 and Henry et al., 1986) have shown that with current management techniques, the efficiency of water conserved is much higher than that in the past even though the amount of water conserved is similar. This is due to the availability of new varieties and greatly improved crop management. It has been demonstrated (J. L. Henry, personal communication) that about 65 mm of available water is necessary in the Brown soil zone before one can expect any yield of wheat. This, however, decreases progressively to 48 mm in the Dark Brown, 41 mm in the Black and 38 mm in the Dark Gray soil zone. Beyond these thresholds, yield increases ranging from about 9.2 kg/ha in the Brown to 12.5 kg/ha in the Gray soil zone can be expected for each additional mm of water available to the growing plant. Thus, information on spring soil water storage and on how much rainfall can be expected in any given area is very important for estimating yield, and information on the probability of spring available soil water and growing season rainfall is fundamental to estimating production risk.

Traditionally the supply of water through precipitation has been reported as long term arithmetic means, even though rainfall is a stochastic event. This study deviates from such an approach by presenting information in terms of varying levels of probabilities rather than means (the 50 per cent probability level is equivalent to the arithmetic mean). Also, the information is compiled using a soil water model which integrates daily precipitation for a 30 year period, with the water storage capacity of the soil, to estimate the amount of water available to spring wheat for each day of each growing period. Furthermore, estimates are provided for different phenological growth stages, and for different crop rotations. These estimates are made for different soil water-holding capacities, within each of the soil zones (Agroecological Resource Areas). Results are presented as maps showing the distribution of available soil water at different levels of probabilities, for the most common AWC in each area. This information provides a fundamental understanding of the variability of available soil water across the different regions of the Canadian prairies, and the probability of a given level of growing season precipitation. This information reflects varying levels of production risk, and it can be used as an aid for decisions on farm practices, such as planting decisions, summerfallowing or extended rotations. It can also be applied to policy and program decisions.

METHODOLOGY

Agroecological Resource Areas (ARAs) were employed to disaggregate the prairie region into relatively homogeneous biophysical land units. Plant available water was calculated for each ARA for the 1955-1985 period, and the results were subjected to a probability analysis. Further details on data, methods and assumptions follow.

Agroecological Resource Areas (ARA)

The agricultural portion of the prairies was divided into ARAs to provide a natural, soil landscape based framework for regional agricultural land evaluation. The criteria used to distinguish each ARA were based on agro-climate, surface form, soil texture and soil development. Each ARA was considered to be generally similar in terms of agricultural potential, land use and management (Pettapiece, 1989; Eilers and Mills, 1990; G. Padbury, personal communication).

The dominant Available Water-holding Capacity (AWC) of each ARA was obtained by manually overlaying the ARA map with the maps published by De Jong and Shields (1988). Because the latter maps often did not distinguish between soils having 50 or 100 mm AWC, these two classes were grouped for mapping purposes and assigned an AWC of 100 mm. Consequently four AWC classes were recognized, namely 100, 150, 200 and 250 mm, representing respectively sand, loam, clay loam, and clay soils (Fig. 2). ARA's dominated by Solonetzic soils, organic soils and high water tables were excluded from further analysis because the concept of available water as used herein did not apply to these soils.

The AWC map of the ARA's (Fig. 2) sometimes did not coincide exactly with the maps published by De Jong and Shields (1988), because of scale differences in the base documents. Consequently small polygons delineated by De Jong and Shields did not show up as dominant areas within an ARA. Moreover the ARA boundaries in Alberta did not always coincide with the polygon boundaries on the AWC maps of De Jong and Shields. Whenever this occurred, the AWC estimate was based on the largest area of the ARA falling within a given AWC of the base map.

Some problems in mapping were experienced along the provincial boundaries. A large proportion of the soils in north-eastern Alberta were mapped as clay loams, whereas those across the border in Saskatchewan were mapped as loams. Similar, but less extensive problems occurred along the Saskatchewan/Manitoba border, but these were predominantly problems of local bias. No attempts were made to correct for boundary inconsistencies. The impact of this can be observed on some of the final maps, particularly if values in immediately adjacent areas on both sides of a border fell very near to the limits between two classes.

Climate Data

Daily weather data from 1955 to 1985, including maximum and minimum air temperature, precipitation and potential evapotranspiration were derived for each ARA using the Thiessen polygon weighting technique (Williams and Hayhoe, 1982). The technique was applied to a network of 165 climate stations for the 1955-65 period and 175 stations for the 1966-85 period. The full period was broken into these two segments in order to make maximum use of all available climate data. The weighting coefficients were checked and, when necessary, adjustments based on non-representative station elevations were made by local experts in each province.

Modelling

The modelling methodology (De Jong and Bootsma, 1988) used the Versatile Soil Moisture Budget (VSMB) (Baier et al., 1979) to estimate the components of the soil water balance for spring wheat. These procedures are based on the premise that water available for plant growth is gained by precipitation, but lost by evapotranspiration, runoff and deep drainage. The net loss or gain each day is added to the water already in the rooting zone of the soil. Water is withdrawn simultaneously, but at different rates, from different depths in the soil profile, depending on the rate of potential evapotranspiration, the stage of crop development, the water release characteristic of the soil and the available water content.

The soil was subdivided into six standard zones, each having an available water-holding capacity calculated as a percentage of the total AWC (Baier et al., 1979). Water release characteristics were the same as those used by Sly (1982).

Knowledge of seeding dates is essential for an accurate representation of crop growth and development. Observed data on "date when seeding is general" for spring wheat were obtained from Statistics Canada, Agriculture Division, Ottawa for each Crop Reporting District (CRD) for 1955-1985. The seeding date was then estimated for each ARA, by manually overlaying the ARA map with CRD- and land use maps (A. Mack, personal communication) and determining weighting factors based on the approximate fraction of cultivated land in each CRD located within an ARA.

The rate of water uptake by the roots was simulated by crop coefficients which change as the crop goes through five phenological stages: seeding, emergence, jointing, heading, soft dough and maturity (or harvest). The duration of each growth stage was defined by a biometeorological time scale model (Robertson, 1968), which required air temperature and photoperiod data. The latter were calculated at the ARA's centroid latitude, using astronomical equations (Robertson and Russelo, 1968). No direct consideration was given to the effect of soil water conditions on phenological development.

The snow budgeting procedure, described by Baier et al. (1979) was used during the winter period to provide estimates of soil water reserves in spring; it also permitted the computer program to run continuously for the number of years for which data were available.

Assuming a wheat/fallow rotation, a single computer run using climate data for the 1956-1985 period provided only 15 years of soil water data under a wheat crop and 15 years under summerfallow. An additional 15 years of data for both the crop year and the fallow year were obtained by restarting the second run with a fallow year, if the first run started with a crop year. In this way a total of 30 years of data were generated for both the crop and fallow year. For continuous cropping a single computer run over 30 years was sufficient. Each computer run started with an assumed water content of 50% of the maximum possible on 15 April, 1955, which was the year prior to the first one used.

The difference between soil water content at seeding in a continuous wheat rotation and that in a wheat/fallow rotation was calculated and designated as "extra soil water conserved by fallowing". Daily precipitation and potential evapotranspiration were accumulated between the observed seeding date and the calculated maturity or harvest date.

Probability Analysis

Probability analyses for each of the 4 AWCs within each ARA were carried out for 7 selected variables (see Table 1), according to the procedures described by Spiegel (1961). The range of the 30 year data of each variable was divided into 16 equal sized classes. Relative cumulative frequencies were calculated for each class and fixed probability levels at 5, 10, 25, 50, 75, 90 and 95% were determined by linear interpolation. Each of the fixed cumulative probability levels indicates the likelihood of receiving a value which is less than the reported amount.

Table 1. List of variables which were subjected to the probability analysis.

Variable #	Variable
1	Available soil water at seeding, continuous wheat
2	Available soil water at seeding, wheat after fallow
3	Available soil water at heading, continuous wheat
4	Available soil water at heading, wheat after fallow
5	Extra available soil water conserved by summer-fallowing (approximately 21 months)
6	Cumulative precipitation between seeding and harvest of spring wheat
7	Cumulative potential evapotranspiration between seeding and harvest of spring wheat

Mapping Procedures

The ARA map of the 3 prairie provinces was compiled at a scale of 1:2 million, digitized and stored in a Geographical Information System (GIS). All calculated probability levels of the 7 variables (Table 1) for each AWC were entered in the GIS as attributes of each ARA polygon. Maps for the 10, 50, and 75% probability levels were then generated by selecting the data pertaining to the dominant AWC in each ARA. To improve the readability of the maps, the values for each fixed probability level were grouped into 7 or 8 classes, resulting in class intervals varying from 20 mm for extra available water conserved by summerfallowing to 50 mm for cumulative precipitation between seeding and harvest. Boundaries between individual ARAs were deleted.

RESULTS

Interpretation of the Maps

Because the values for each fixed probability level were grouped into classes, the cumulative probability levels on each map refer to values which are less than the reported class as opposed to less than the actual computed value. For example the ARA north-east of Winnipeg has a 10% probability that the soil water content at seeding (continuous wheat) is less than 145 mm. The ARA located south-west of Winnipeg has a 10% probability that the soil water content at seeding is less than 136 mm. For mapping the 10% probability values, these two ARAs were combined in the 131-160 mm class and thus it is reported (Fig. 3) that the entire Winnipeg area has a 10% probability that the soil water content is less than 131-160 mm. In other words, 1 year in 10 the soil water content at seeding does not exceed 131-160 mm in the Winnipeg area, or conversely, 9 years out of 10 the soil water content is higher than 131-160 mm.

Soil Water Content at Seeding

Yields of spring wheat on the Canadian prairies are largely dependent on the amount and distribution of growing season precipitation and spring soil water reserves. Proper crop establishment requires that sufficient water be available at seeding time, especially in the surface soil. Figure 1 shows the location of the major soil zones in the prairie region, and Figure 2 shows the distribution of available water holding capacity (based on the dominant soil texture).

Estimates of available soil water content (SWC) at seeding are presented in Figures 3, 4 and 5 for 10, 50 and 75% probability, respectively, for continuous wheat. In most of the Brown and Dark Brown Chernozemic soil zones (see Fig. 1) in southeastern Alberta and southwestern Saskatchewan, SWC does not exceed 11-40 mm at 10%

probability (1 year in 10) regardless of soil AWC (Fig. 3). SWC is typically less than 41 to 70 mm in the same area at the 50% probability level (Fig. 4). In 3 years out of 4 these soils typically do not exceed 71-100 mm of available water at seeding (Fig. 5). The lighter textured soils in the same area do not exceed 41-70 mm at the 75% probability level.

Estimated SWC at seeding in the crop year of a wheat/fallow rotation are somewhat higher than continuous wheat for all three probability levels (Figs 6, 7 and 8). Soils in the Brown and Dark Brown Chernozemic zones typically have SWC which do not exceed 71 to 130 mm at the 50% probability level, although some ARA'S have a value below 70 mm (Fig. 7). In the Black Chernozemic soil areas SWC is typically 101-160 mm at 50% probability, although a few ARA's outside this range can be found. The fine textured soils (AWC = 200 and 250 mm) have 160-225 mm.

Soil Water Content at Heading

The distribution of growing season precipitation and available soil water has a significant influence on grain yield. Wheat appears to be most sensitive to water stress at the grain development or heading stage (Bauer, 1972; Desjardins and Ouellet, 1980; Campbell et al., 1988).

Estimates of SWC at heading for continuous wheat are presented in Figure 9, 10 and 11 for the 10, 50 and 75% probability levels, respectively. SWC of 30 mm is not exceeded 1 year in 10 (10% probability) for much of the prairie region (Fig. 9). The average (50% probability) is approximately the same as in Fig.9 for southeastern Alberta and southwestern Saskatchewan, as well as the sandy soils (AWC = 100 mm) (Fig. 10). Higher water contents are experienced in parts of eastern Manitoba and northern Alberta. At the 75% probability level (not exceeded 3 years out of 4), SWC are typically 31 to 91 mm, although some ARAs exceed 121 mm (Fig. 11).

As expected estimates of SWC at heading for wheat/fallow rotations (Figs 12, 13 and 14) are higher than for continuous wheat, although in Saskatchewan, Figures 9 and 12 are very similar. However, differences are considerably smaller than at seeding and this reflects the fact that some of the extra water available at seeding has been utilized by increased water use from seeding to heading by fallow-seeded crops.

Extra Water Conserved by Fallowing

One of the objectives of summerfallowing is to store extra water in the soil during the fallow period that will be available for growth the following spring. In this way summerfallowing can be an effective measure for reducing risk of inadequate rainfall during the growing season, particularly in the Brown and Dark Brown Chernozemic soil zones.

It has been estimated that average yield increases of about

8.5-10 kg/ha for spring wheat can be expected for each mm of additional water conserved in the soil (De Jong, 1990). With superior soil fertility, weed control and reasonable growing season rainfall distribution, water use efficiencies can be as high as 12.5 kg/ha per mm (Table 2).

Table 2 - Approximate water use efficiencies for spring wheat in each of the major soil groups in southern Saskatchewan (J. L. Henry, personal communication).

Major soil zone	W.U.E. (kg/ha per mm)
Brown	9.2 - 9.8
Dark Brown	10.5 - 10.8
Black	11.2 - 11.8
Gray	12.5

The amount of extra water conserved by fallowing varies with soil type, climate and seasonal weather conditions. Estimates of extra water conserved by one year fallowing are presented in Figures 15, 16 and 17 for probability levels of 10, 50 and 75%, respectively.

Figure 15 indicates that during 1 year out of 10 there will be less than 20 mm of extra water conserved in much of the prairie region, except in western Alberta and the Peace River region. Consequently yield increases of 200 kg/ha or less may be expected in these years. At 50% probability (Fig. 16) the amount of extra water conserved is 40 mm or less in most of the prairie region. However this is increased to 41-80 mm in parts of Western Alberta, areas north of Edmonton, and for much of the Peace River region. At the 75% probability level less than 21-60 mm extra water is conserved for much of the prairie region, but less than 81-100 mm in the Peace River region.

The northern prairie region has the greatest potential for conserving water, but these are not the areas where water storage is most required. The driest areas where summerfallowing is most beneficial for water conservation are in the Brown and Dark Brown Chernozemic soil zones in southeastern Alberta and southwestern Saskatchewan. Extra water conserved by fallowing in these regions is typically less than 40 mm at the 50% probability level (Fig. 16), although in some years and areas the amount can be 61-80 mm (Fig. 17). Thus, yield increases due to fallowing may be about 400 kg/ha or less in half the years, but can be up to 800 kg/ha in some years. This represents 20% to 40% of yields currently being realized in these areas. In the wetter parts of the prairies such as the Black and Dark Gray Chernozemic soils and the Peace River area, summerfallowing is usually not required even though relatively large amounts of water can be conserved (e.g. 61-80 mm at 50% probability in the Peace River region (Fig. 16)). Water conservation through summerfallowing is not required in these areas

because energy, rather than water, is the major limiting factor in crop production.

Cumulative Precipitation Between Seeding and Harvest

Rainfall received during the period from seeding to harvest is a crucial factor in the production of spring wheat in the prairie region. In years when rainfall is inadequate for supplying the crop requirements, available water stored in the soil at seeding can also be utilized. Assuming a water use efficiency of approximately 10 kg/ha per mm, crop yields of 2000 to 3000 kg/ha should be achievable in the fringe areas (i.e. Black and Dark Grey Chernozemic and Gray Luvisols which receive 200-300 mm of rainfall in the period from seeding to harvest at 50% probability (Fig. 19)). Soils in the Brown and Dark Brown Chernozemic zones receive rainfall of 100-200 mm at 50% probability, and therefore, based on growing season rainfall only, yields of less than 2000 kg/ha should be achievable. However, water stored in the soil in spring is also made available to the crop and this reduces the risk of inadequate rainfall.

At the 10% probability level (1 year in 10) accumulated rainfall from seeding to harvest is in the 51-100 mm range for most of the southern prairies in Alberta and Saskatchewan, and it is 101-150 mm in most other areas (Fig. 18). At the 75% probability level (Fig. 20) the Brown and Dark Brown Chernozemic regions receive less than 150-200 mm rain, while most of the Black Chernozemic areas receive less than 200-250 mm. Much of the fringe areas and the Peace River region receive 250-300 mm or more once every 4 years.

Cumulative Potential Evapotranspiration Between Seeding and Harvest

Potential evapotranspiration (PE) is defined as the amount of water lost from the soil and plant surfaces as water vapour, if the ground was continually well supplied by water. Under conditions of no water stress, actual evapotranspiration would approach PE values and thus provide a measure of the potential yield that could be achieved under zero water stress.

Cumulative PE is not only determined by temperature (higher temperatures produce higher PE) but also by the number of days required to progress from seeding to harvest. Since this is longer in cooler areas, these regions may not have lower cumulative PE values. Amounts of cumulative PE from seeding to harvest are presented in Figures 21, 22 and 23 for the 10, 50 and 75% probability levels respectively. At 10% probability cumulative PE values are typically less than 350-400 mm, with a few areas exceeding 400 mm (Fig. 21). At 50% probability (Fig. 22), most areas in Manitoba accumulate less than 376-400 mm PE. Most of Saskatchewan and Alberta accumulate less than 401-425 mm PE, although in some areas the accumulated PE is less than 426-450 mm. One year in 4 (75% probability level) PE values are generally less than 451-475 mm in most of the prairie region (Fig. 23).

SUMMARY

The seasonal and spatial variability of soil water on the Canadian prairies is a complex interaction of many variables related to current and past occurrences of weather, crop, soil and agricultural management. Synthesizing all processes involved in tracing the fate of water through the soil-crop-atmosphere system is not possible, but major effects of climate, crop rotation and soil AWC are evaluated and mapped.

The establishment of probabilities associated with the occurrence of climatic events provides a sound basis for the development of viable agricultural strategies for risk management. Determination of these probabilities can be of direct aid to farmers and other decision makers with regard to various aspects of agriculture.

For an individual farmer the soil water content in the spring of the current year is often a "given" fact. But by using this information, plus the growing season precipitation probability maps, he may be able to estimate his grain yield by using an appropriate water use efficiency factor. For example, in the Swift Current area, the amount of available soil water on stubble land in a given spring may be 50 mm. Using a water use efficiency of 10 kg/ha per mm (with proper fertilization and weed control) the expected yield in a year with average (50% probability) seasonal precipitation (150-200 mm, Fig. 19) will be 2000 - 2500 kg/ha (assuming that the precipitation is well distributed over the season). However, there is a 10% probability that the precipitation will be less than 50-100 mm, and under this scenario the expected yield will drop to 1000 - 1500 kg/ha. If a farmer decides to fallow the land until next spring, the extra water conserved will be on average less than 21-40 mm (representing a yield of 210-400 kg/ha), but in 1 year out of 10 less than 20 mm of extra water will be conserved. Whether the farmer will seed in the current year or leave the land fallow until next spring, depends on his willingness to take certain risks.

People involved in agricultural decision making, land use planning and evaluation can use the information in this manuscript in other ways. Their interest may be more focused on the water variables per se, rather than on a derived variable like yield. The presented information can be used as reference material for ongoing measurements and estimates of real time, spatially displayed soil water reserves. (Anonymous, 1989; Henry and Wilkenson, 1979-1990; Mack, 1980-1990; Howard, 1991)

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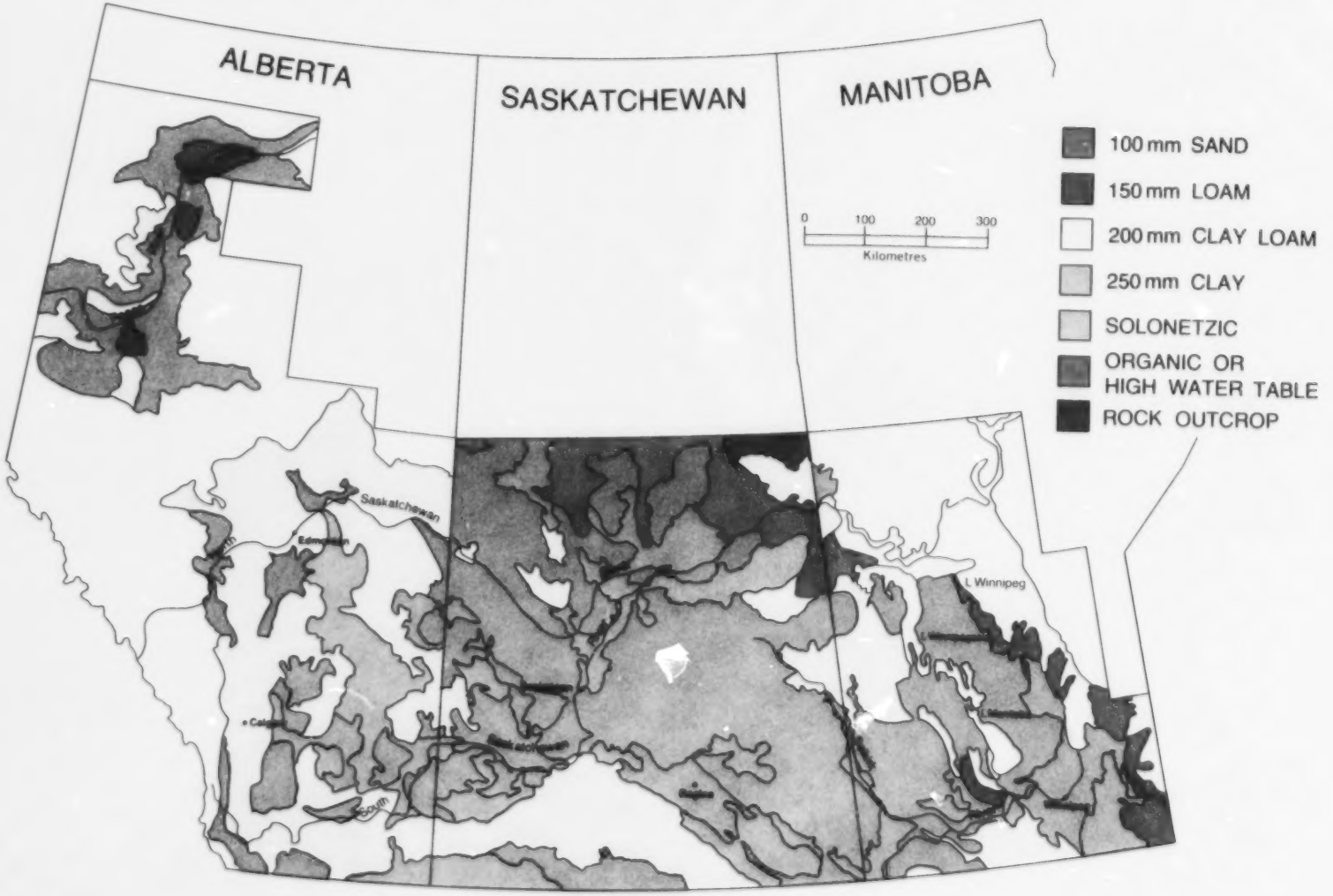


Figure 3. Available soil water at seeding (mm), continuous wheat, 10% probability.

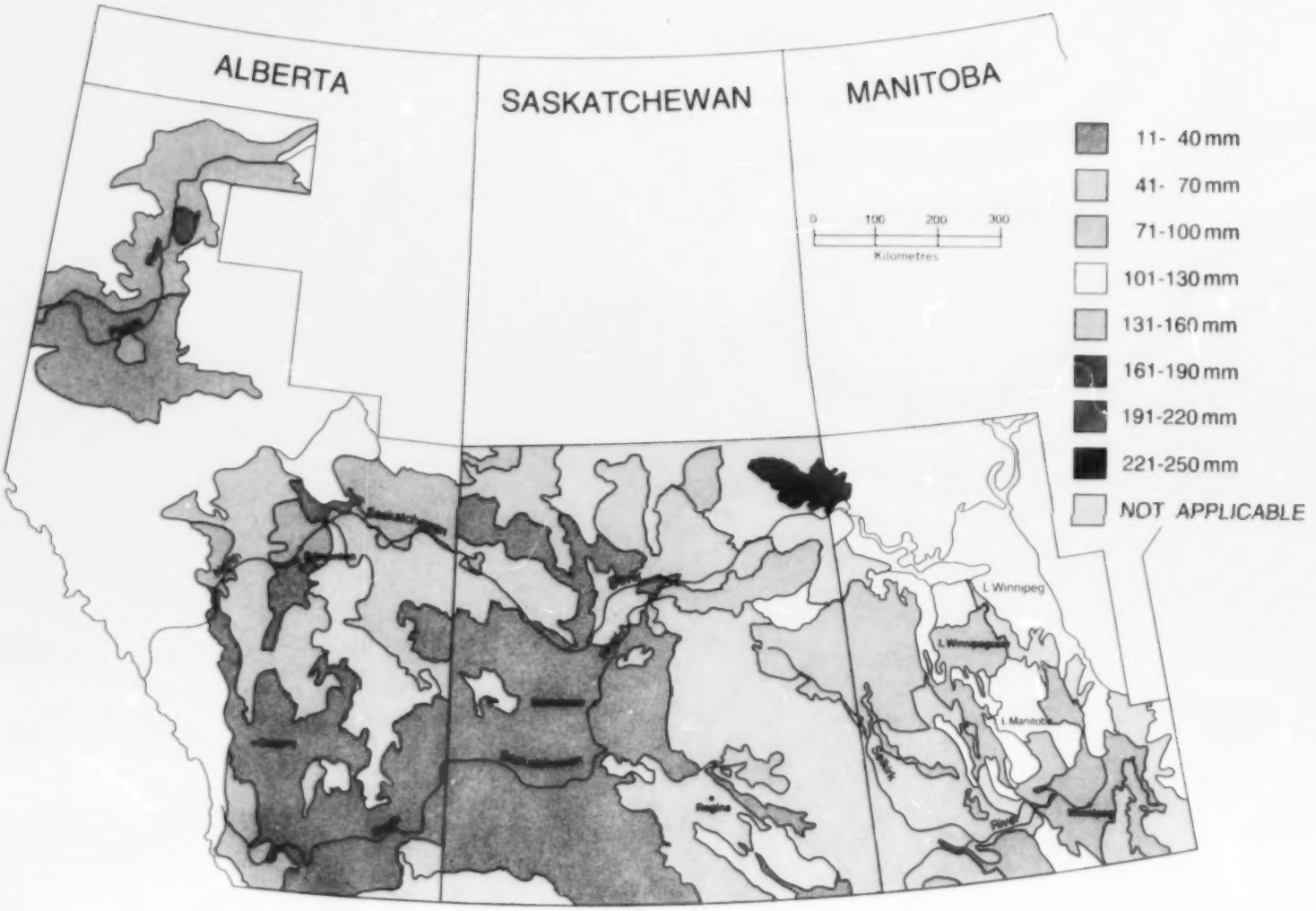


Figure 4. Available soil water at seeding (mm), continuous wheat, 50% probability.

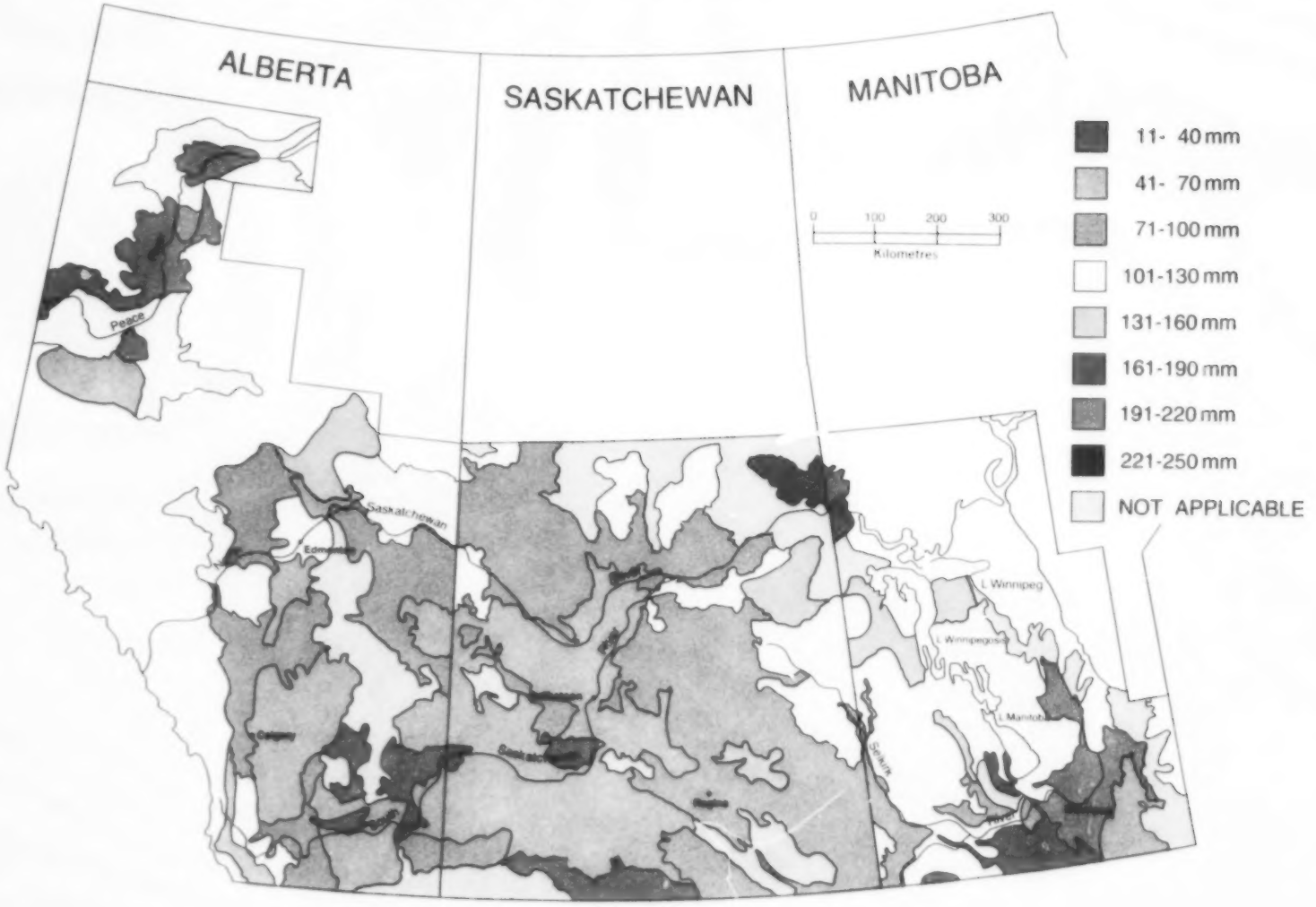


Figure 5. Available soil water at seeding (mm), continuous wheat 75% probability.

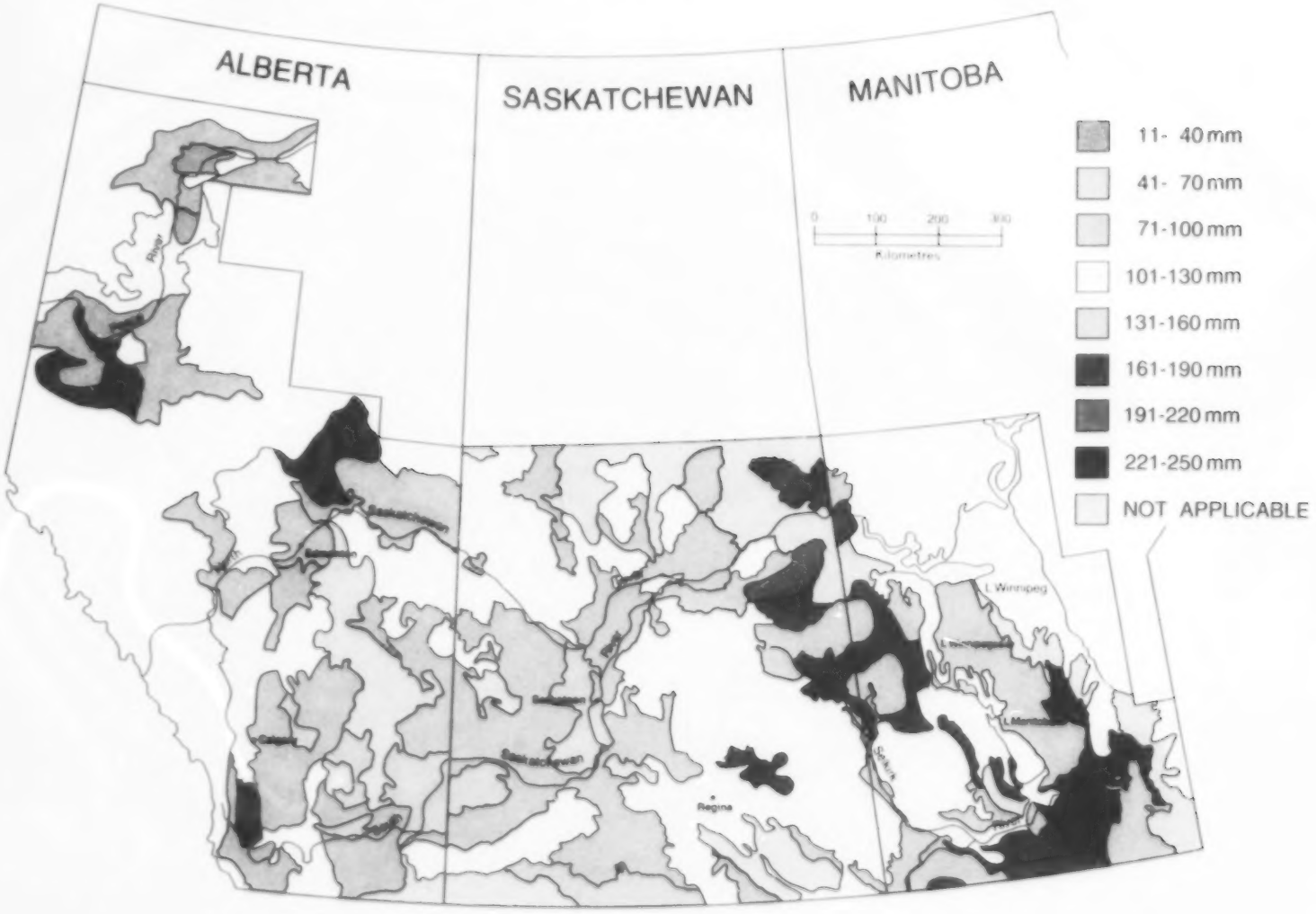
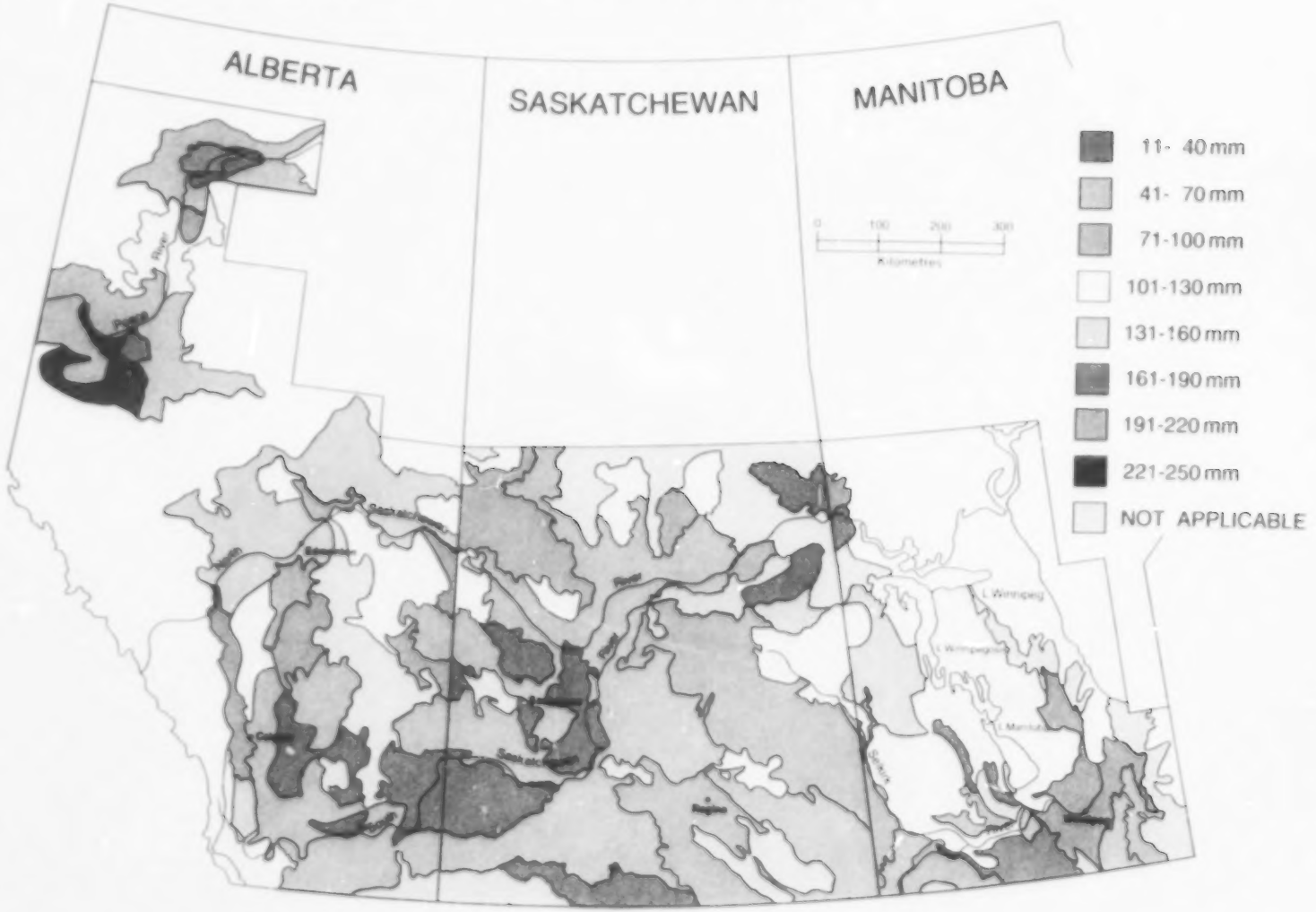


Figure 6. Available soil water at seeding (mm), wheat fallow rotation, 10% probability.



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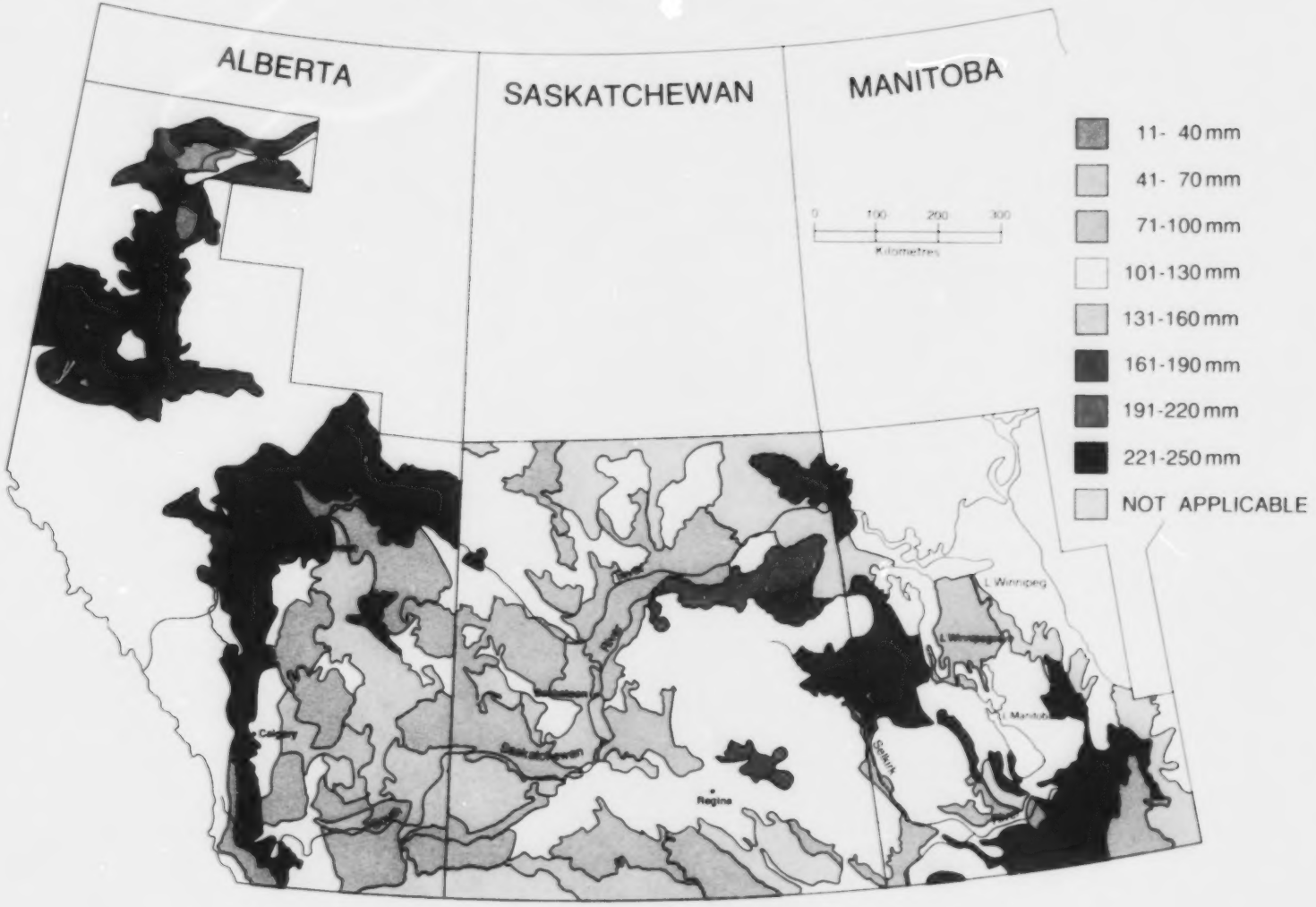

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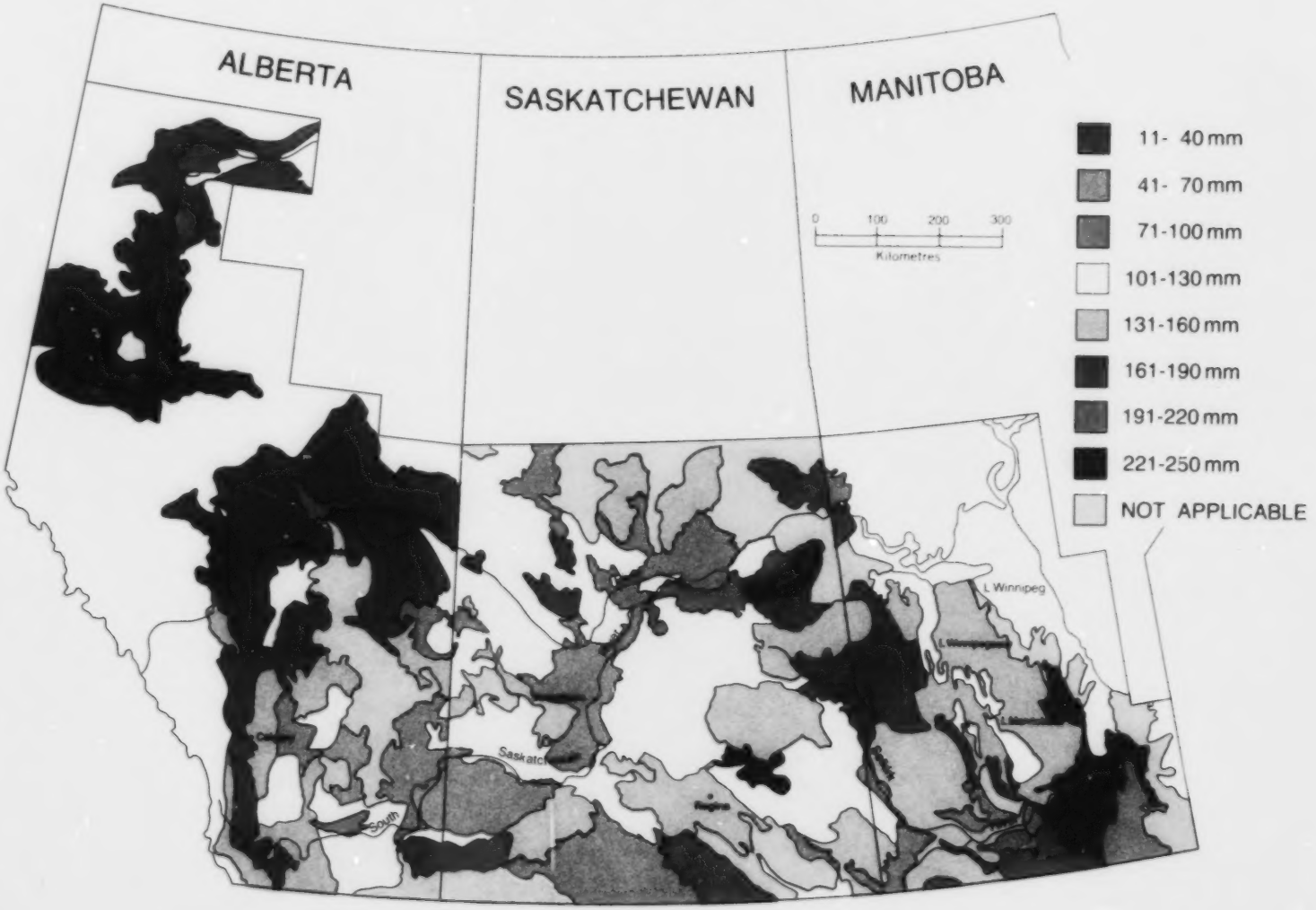

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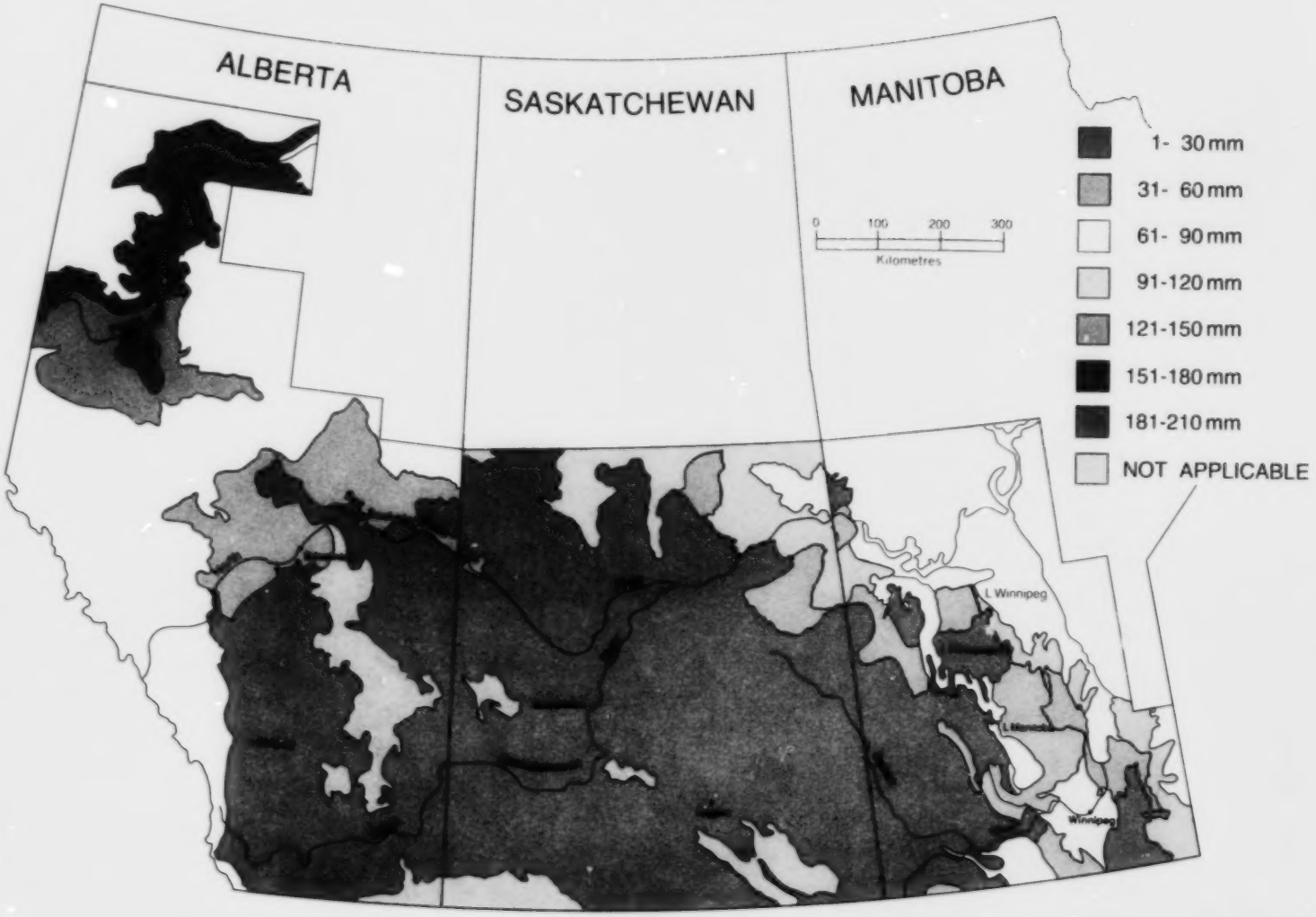

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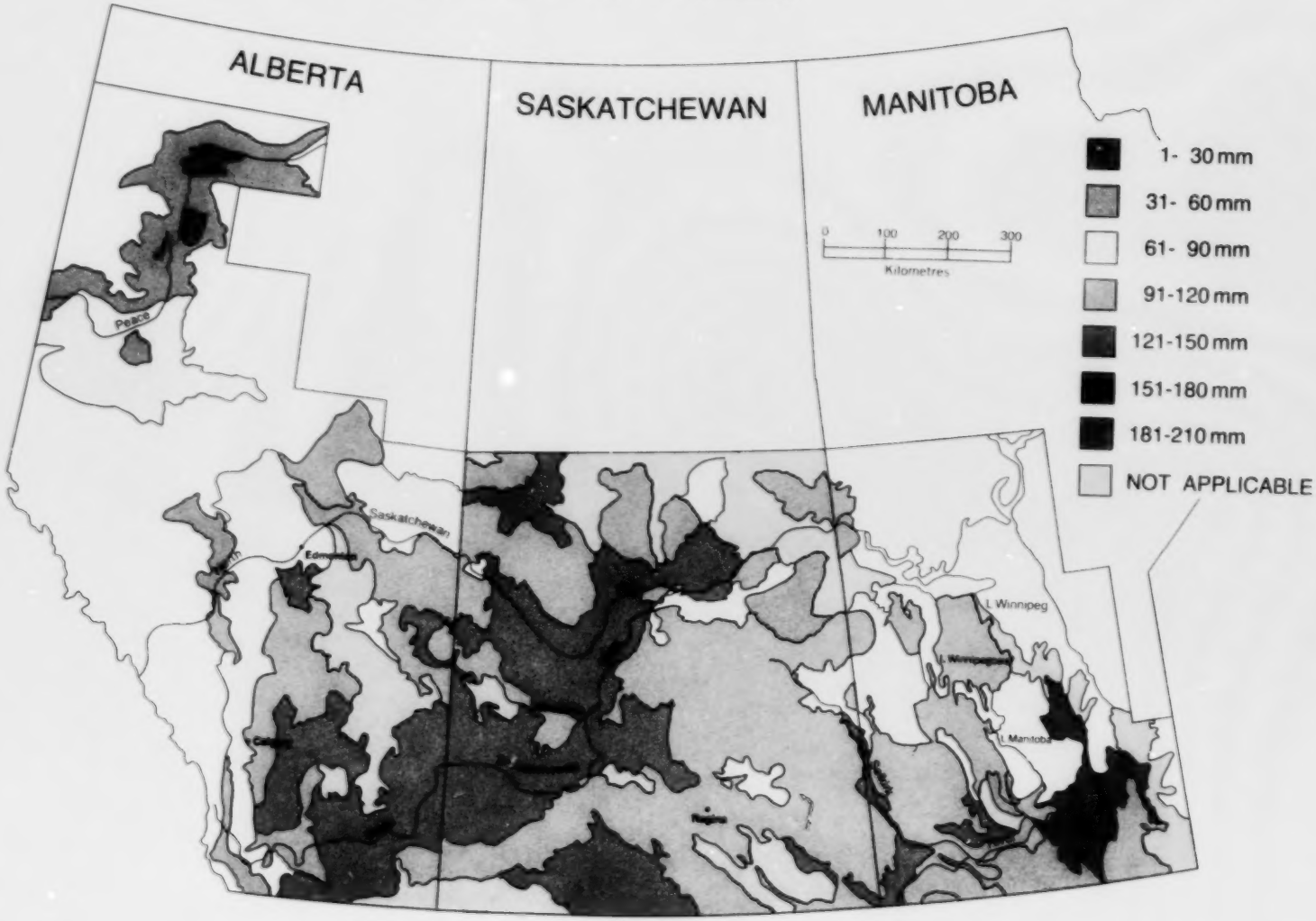

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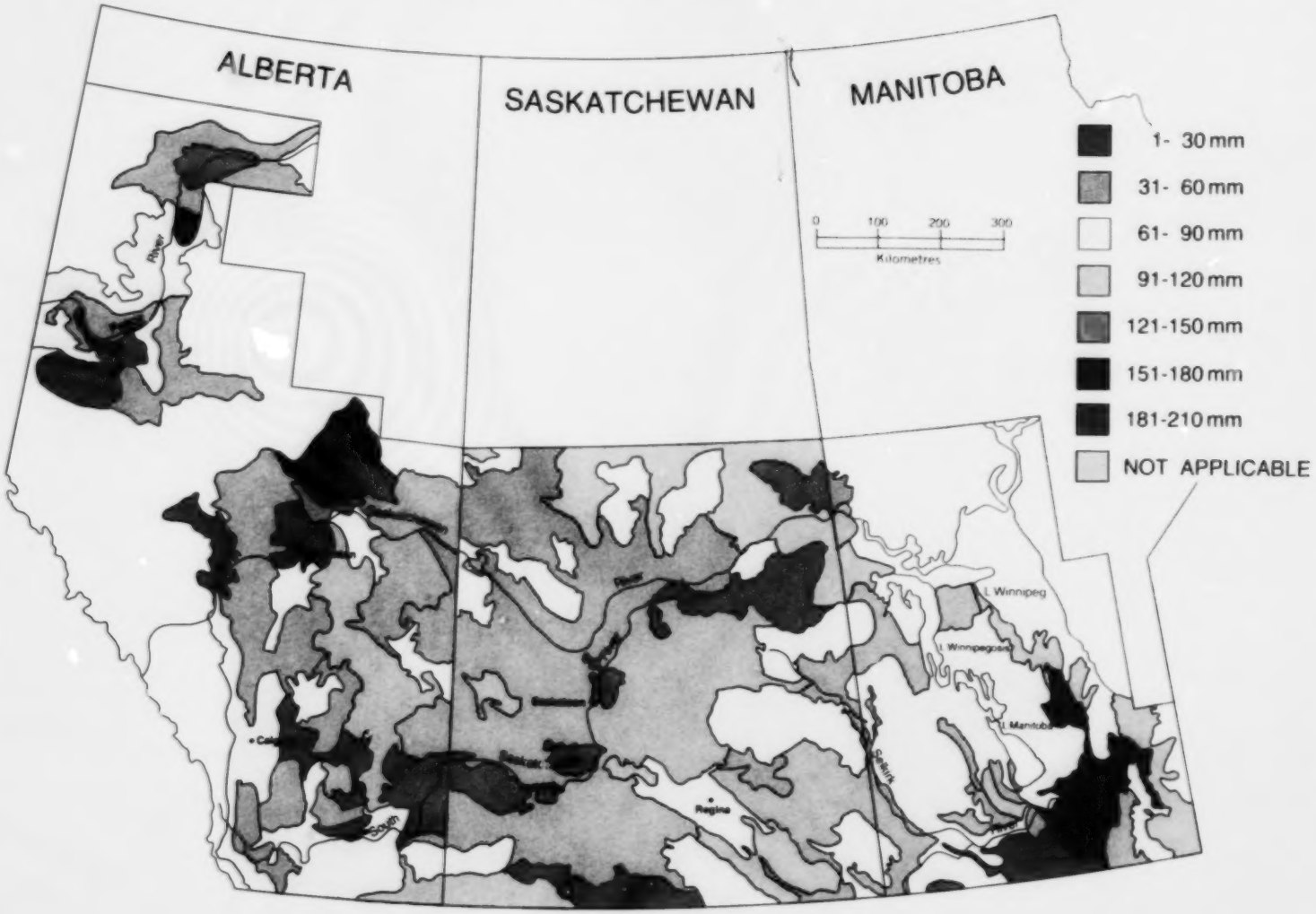

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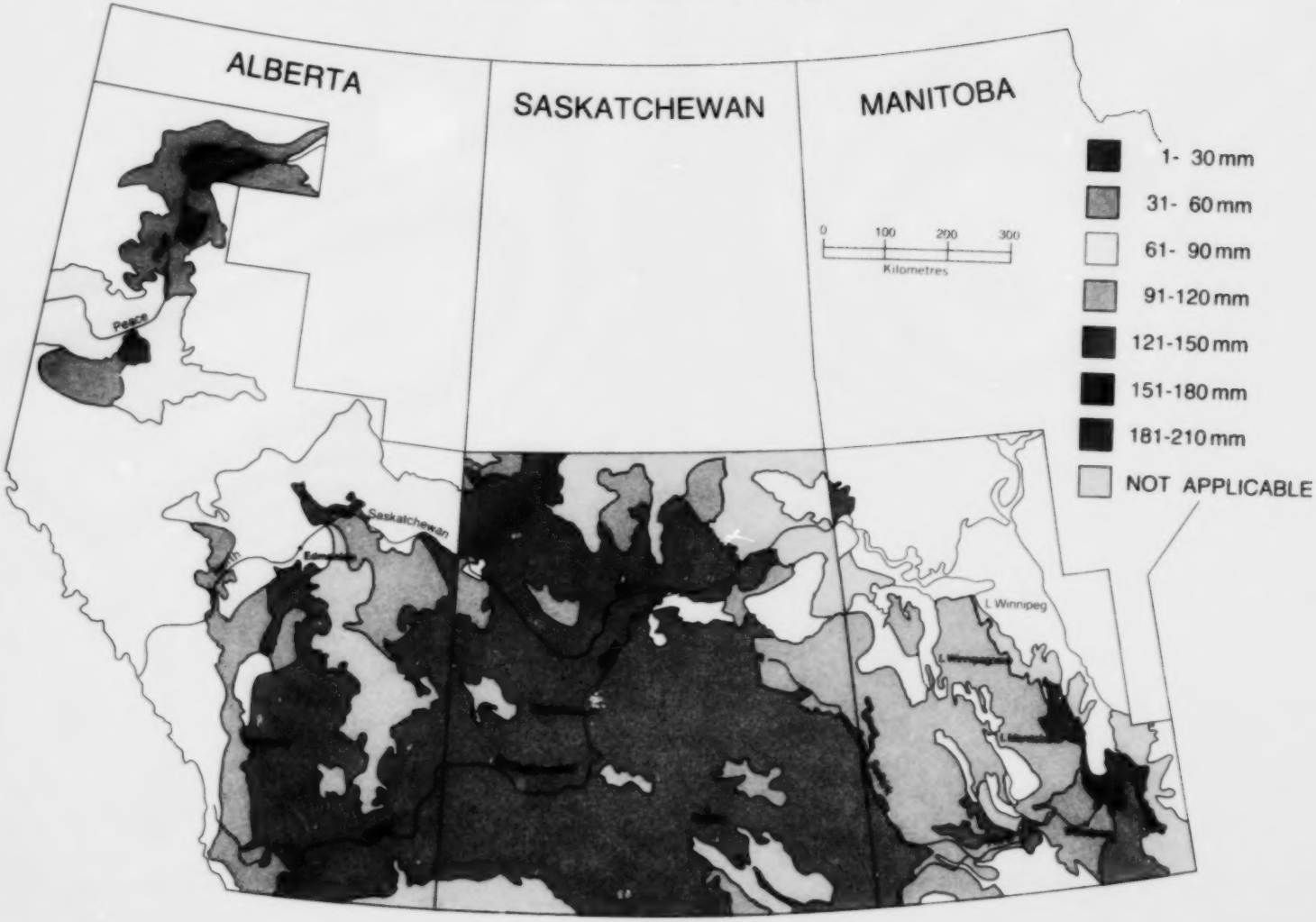

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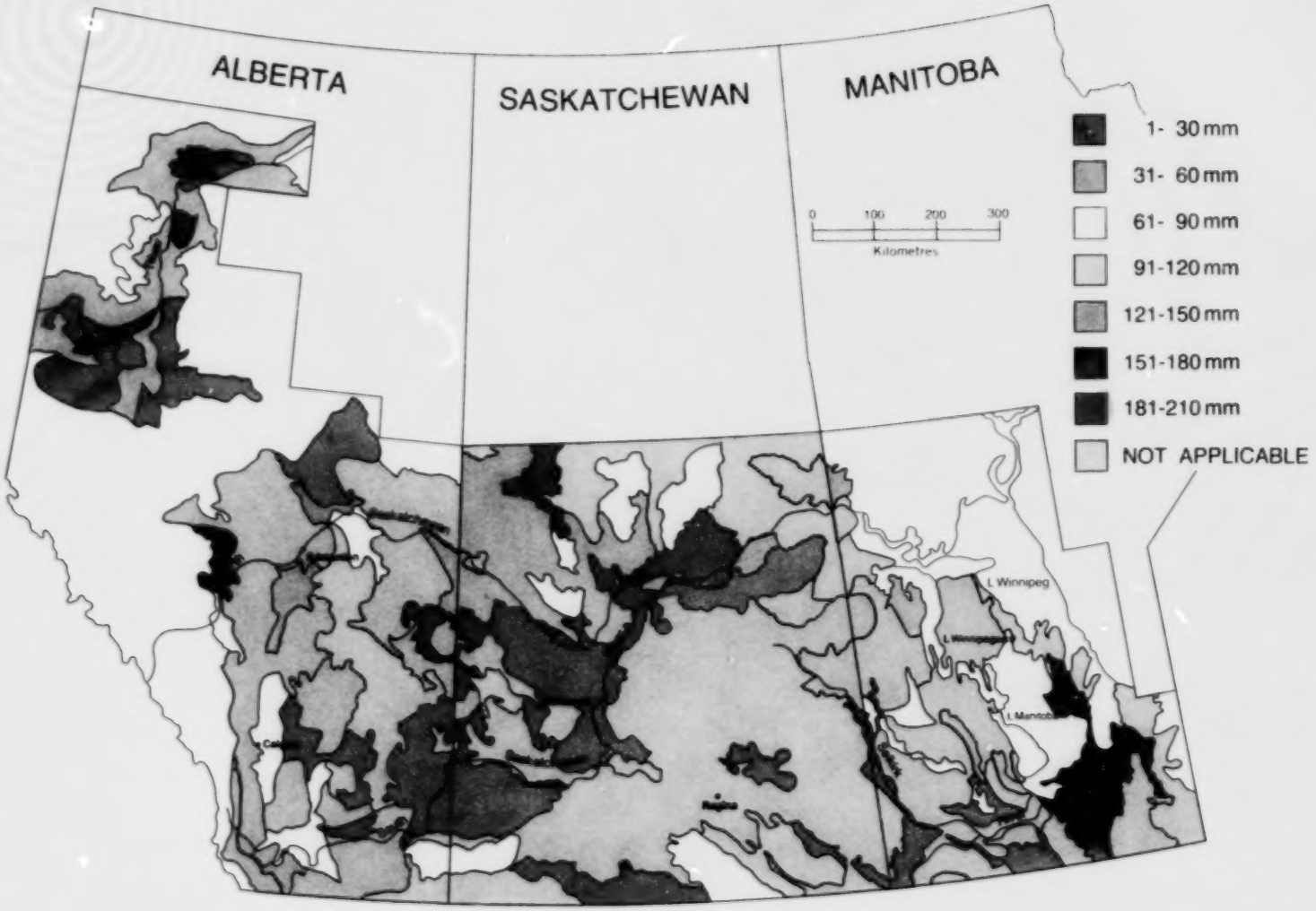

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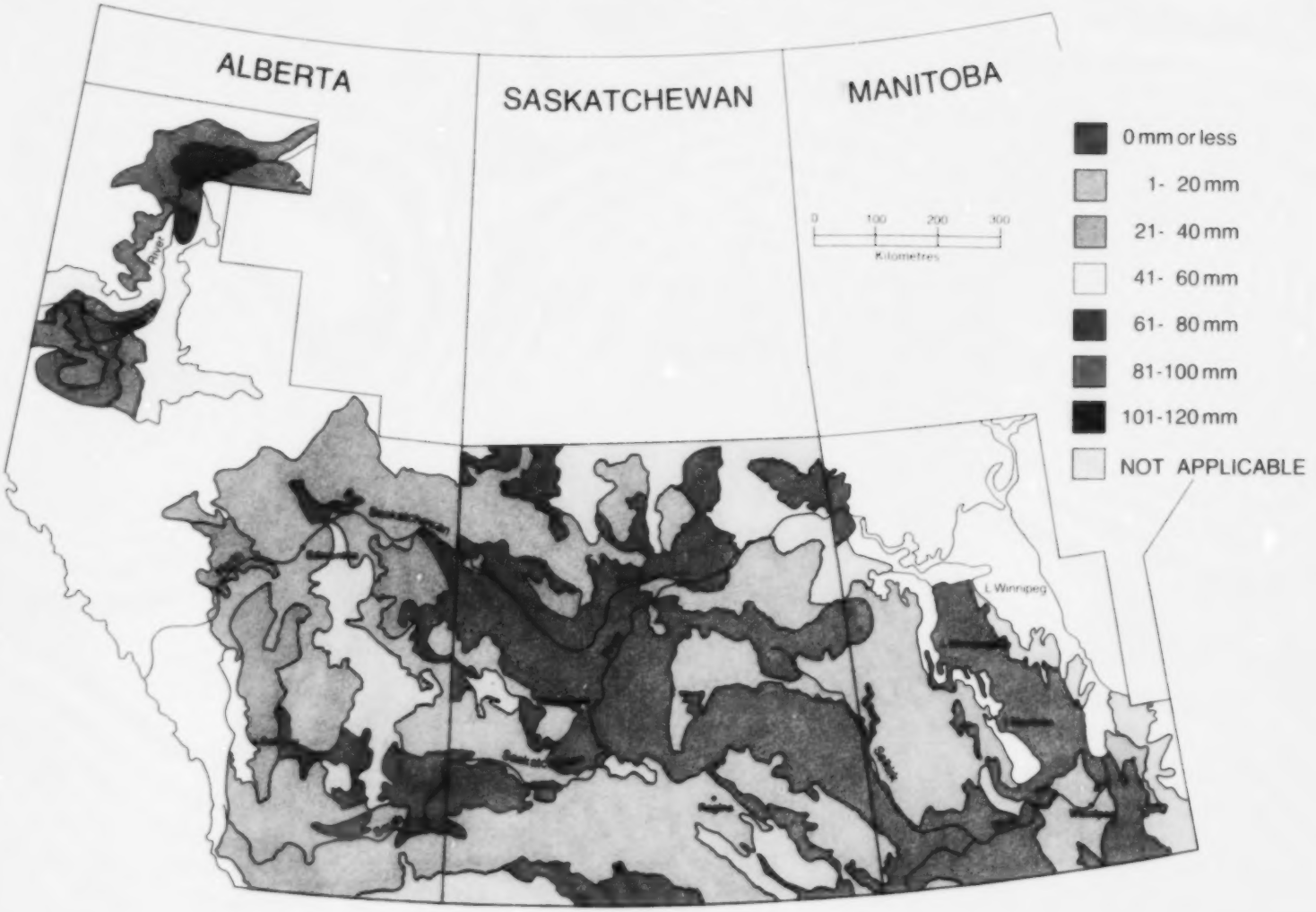

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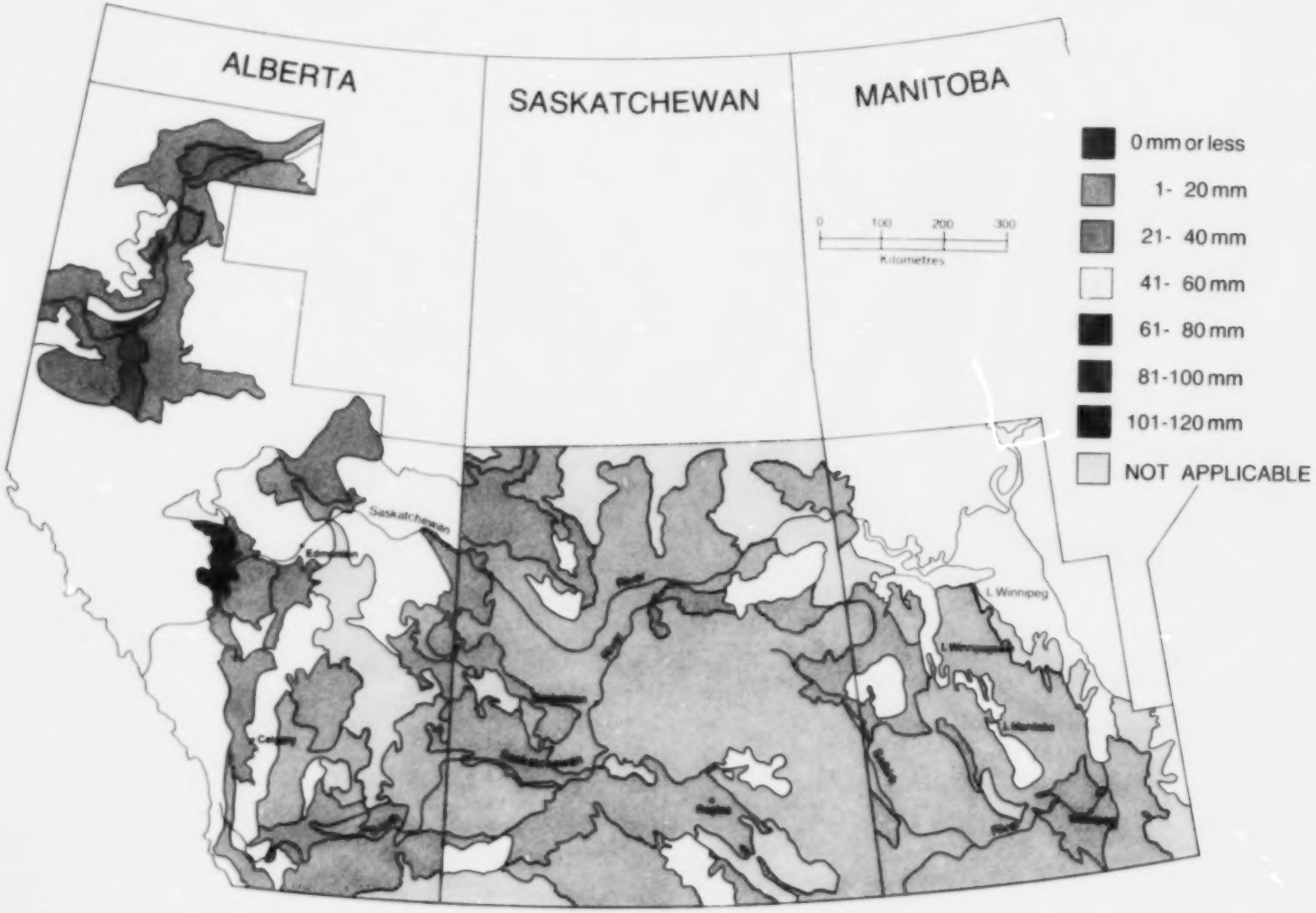

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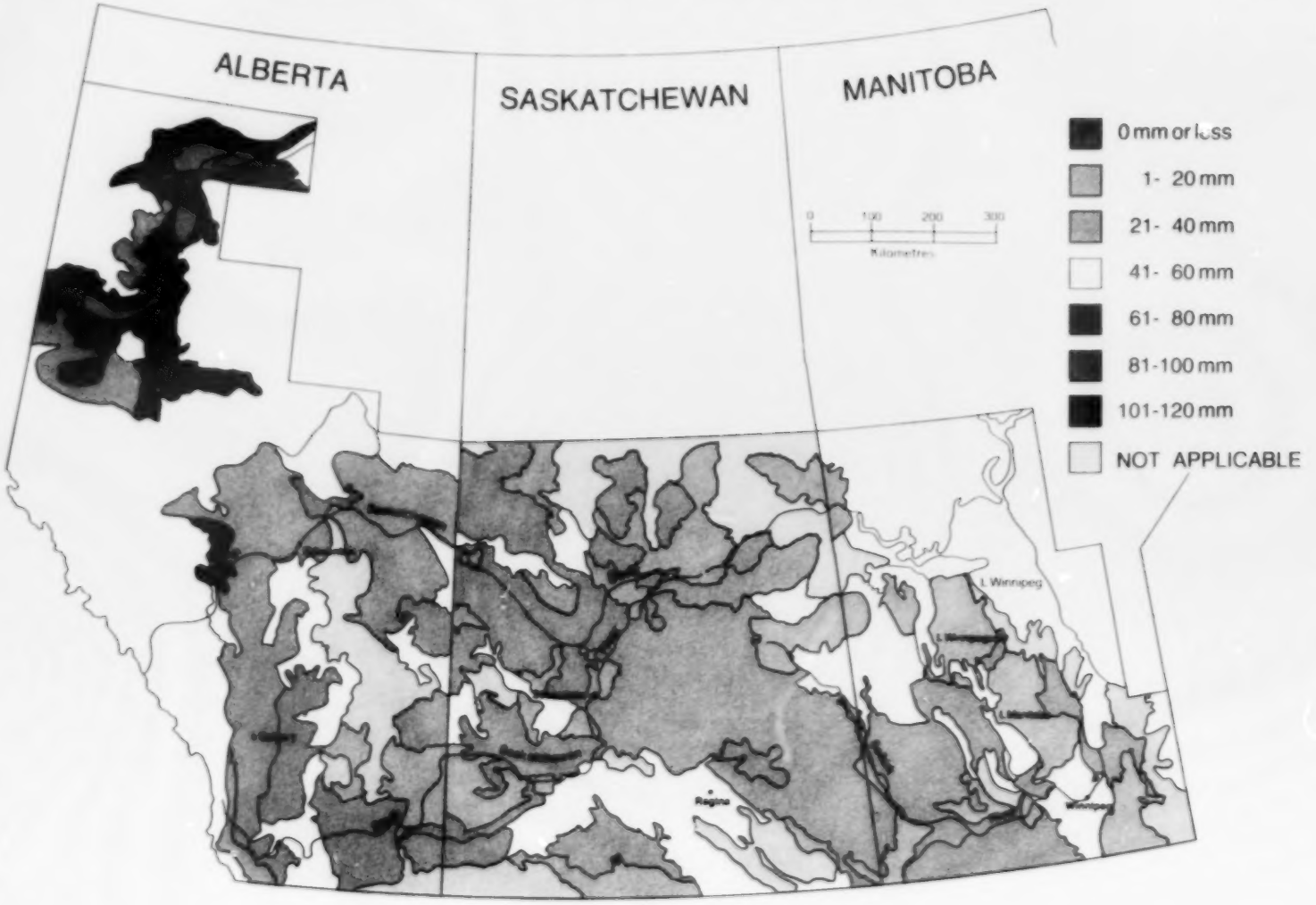

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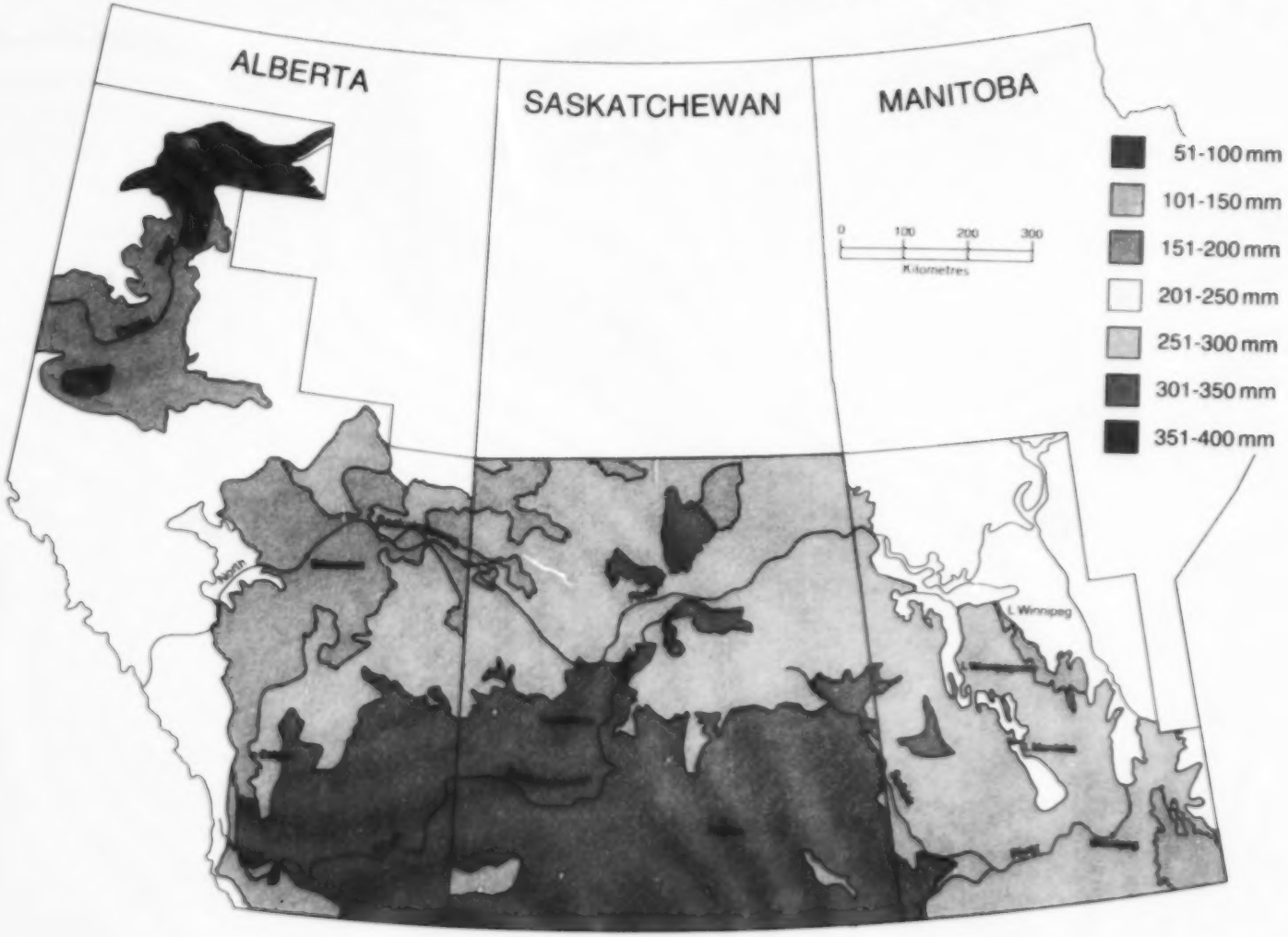

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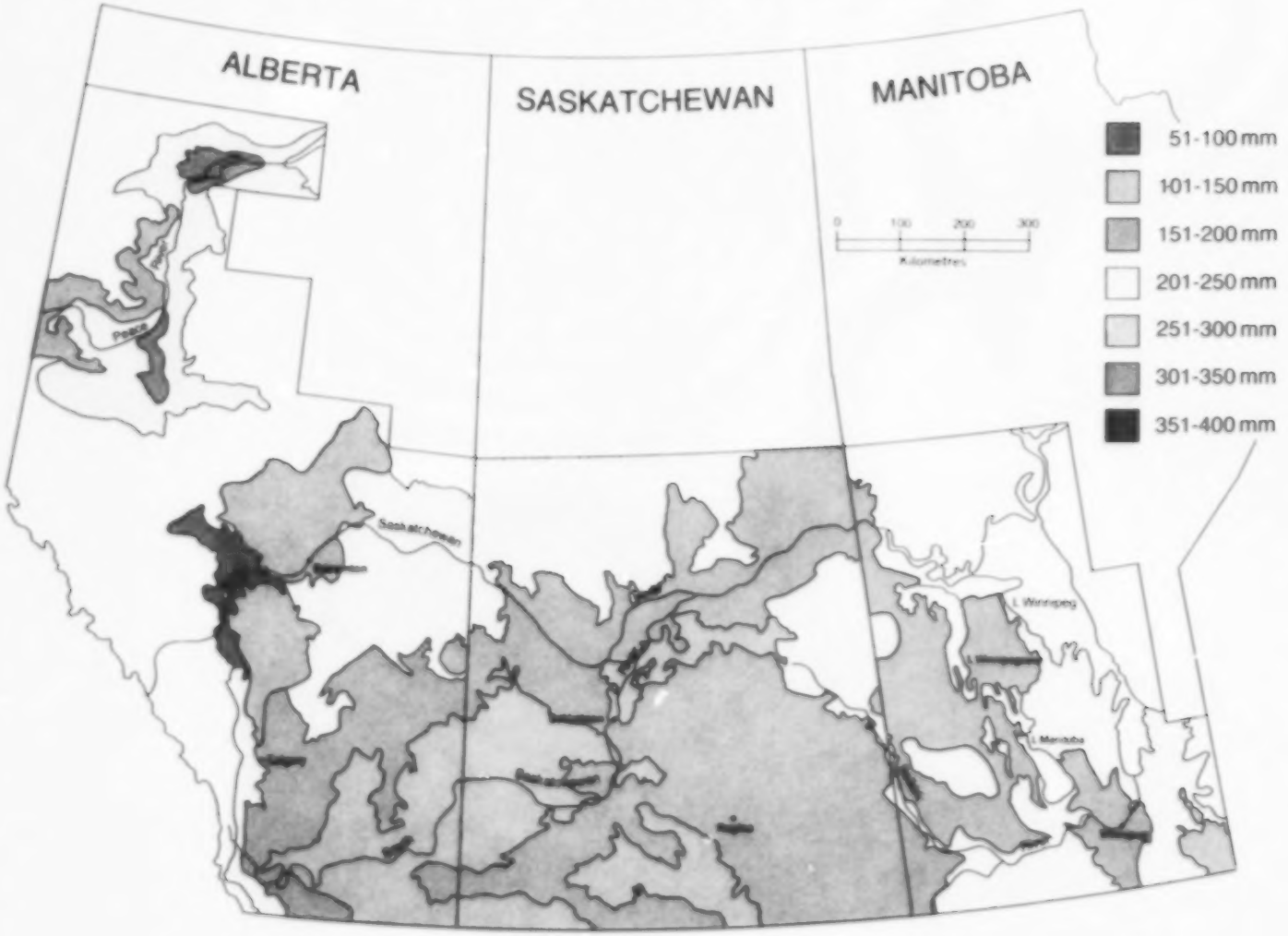

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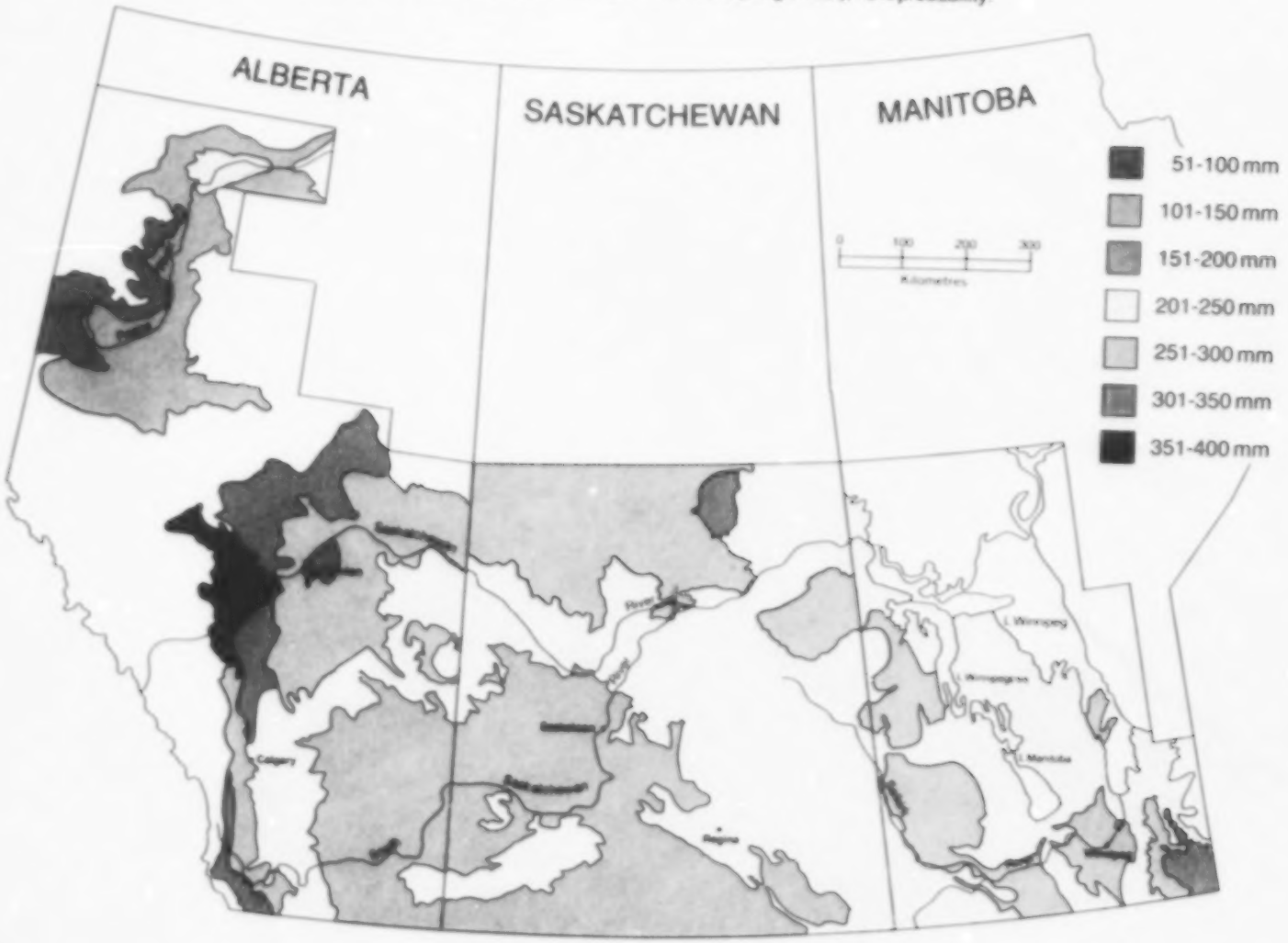

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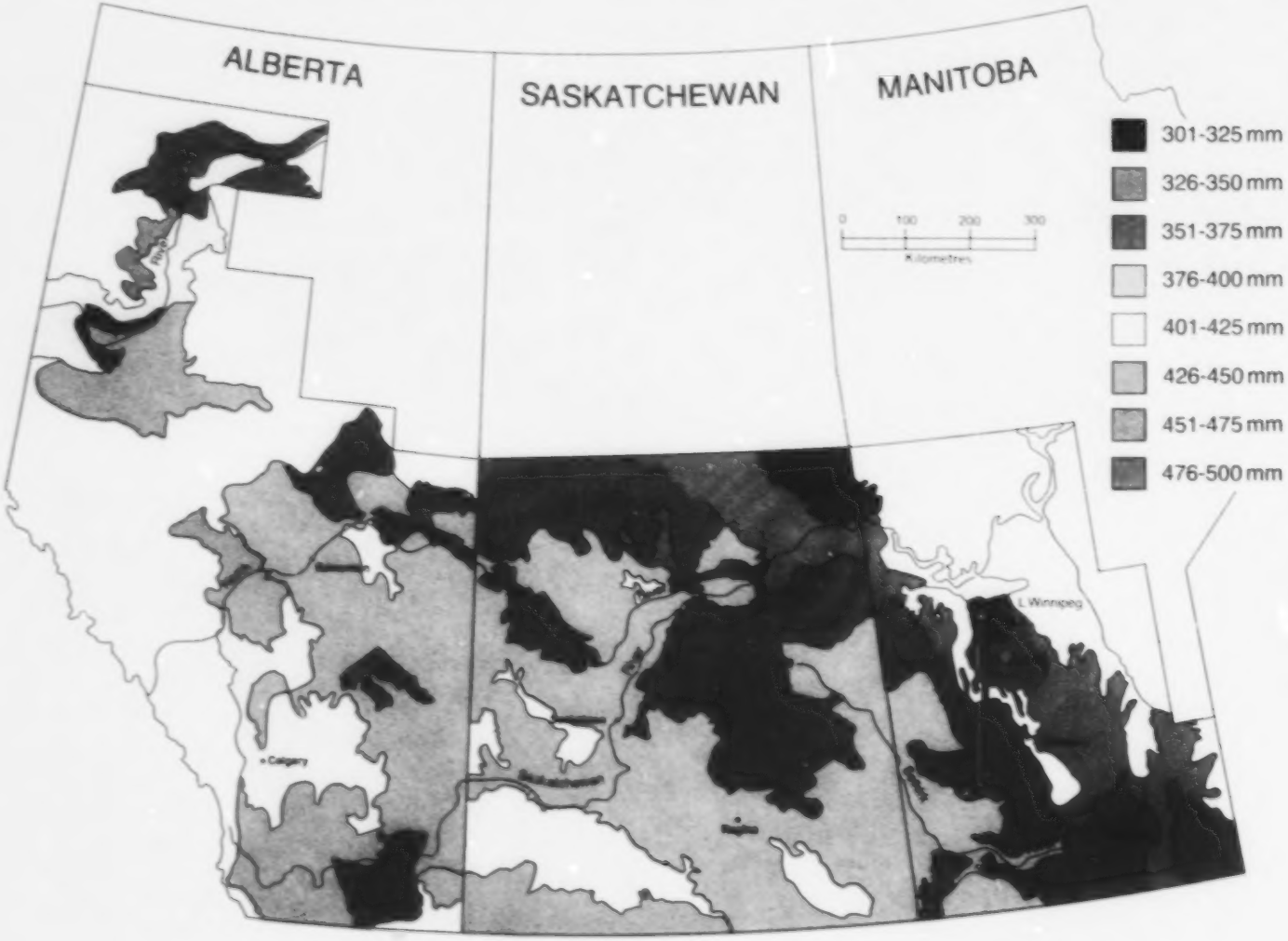

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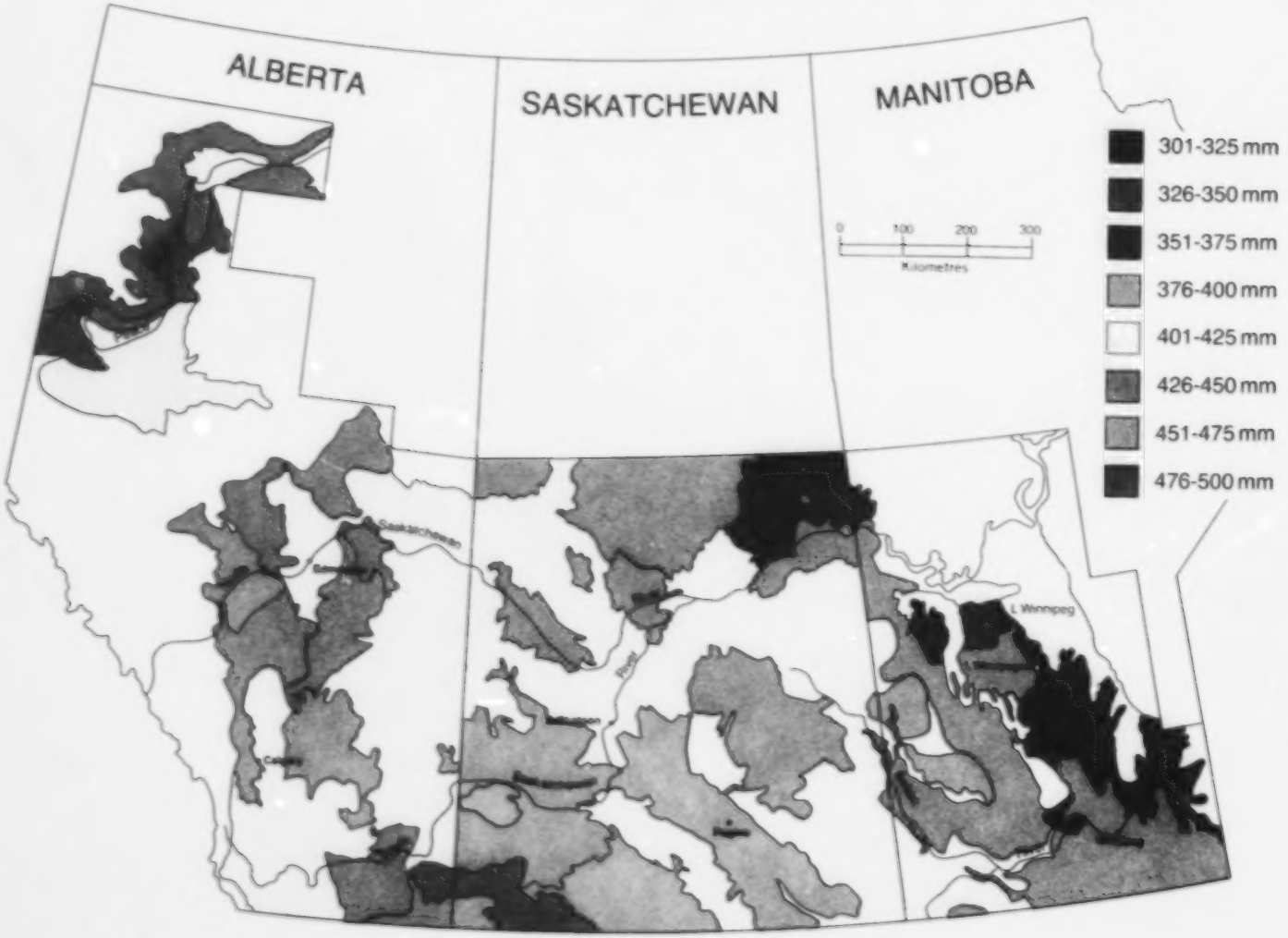

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